

# **Developing a Landscape-Level Reference Standard Wetland Profile for the Prairie Pothole Region, Montana**

Prepared for:

The U.S. Environmental Protection Agency

Prepared by:

Melissa Hart and Linda Vance

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## Executive Summary

In the Prairie Pothole Region, where clusters of wetlands occur within an upland matrix, the individual wetland may not be the appropriate unit for evaluating the impacts of anthropogenic disturbance. Instead, it may be better to emphasize specific wetland landscape profiles as a target. In areas where human disturbance is minimal, wetland abundance, diversity of wetland types, and characteristic wetland size are linked to such landscape-level factors as geomorphology, basin hydrology, and regional or local climate. Consequently, similar landscapes can be expected to have similar wetland "profiles." These profiles in turn help establish which wetland functions are associated with a particular region, and can help inform management and/or restoration programs.

In this study, our goal was to determine whether there are characteristic patterns of wetland abundance, size, and distribution of water regimes in relatively undisturbed landscapes, and assess whether these are significantly different from patterns observed in undisturbed areas.

Our project area was the Prairie Pothole Region (PPR) of Montana, which encompasses 11 Level 4 ecoregions, and contains almost 385,000 mapped wetland/riparian features. To assess human disturbance in the Prairie Pothole Region, we used the Montana human disturbance index (HDI), a raster index integrating six disturbance categories: development, transportation, agriculture, resource extraction/energy development, introduced vegetation, and forestry practices. Within six Level IV ecoregions, we selected 29 paired analysis units representing least and most disturbed landscapes. Each unit was at least 5000 ha in size. We selected wetland/riparian features that fell completely within the analysis units; the least disturbed units held 16,163 features, and the most disturbed units had 20,543 features. Then we summarized wetland types, water flow paths, number of altered wetlands, and water regimes. We also calculated summary statistics for wetland size, density, distance between wetland centroids, and number of landscape complexes and wetland mosaics.

Our results showed few obvious differences between wetland types for least disturbed and most disturbed landscapes. However, disturbance patterns were reflected in the degree of alteration to wetland features. In all but one ecoregion, the percentage of unaltered wetlands was higher in least disturbed landscapes than it was in most disturbed ones. We also found that water permanence appears to be loosely correlated with alteration in most ecoregions, and the data strongly suggest that significant wetland loss has occurred in disturbed areas. Wetland density does not vary greatly across the study area, whether in disturbed or less disturbed patches. Similarly, no clear patterns could be discerned in the occurrence of wetland complexes. As for wetland mosaics, we found them difficult to assess because they so often spilled beyond the boundaries of an analysis unit. We did note, however, that mosaics in less disturbed areas tended to have greater numbers of wetlands and occupy a larger area.

Overall, we did not find strong evidence that characteristic patterns of wetland abundance, size, and distribution are linked to disturbance in the areas we studied, although we did note that there appears to have been a loss of temporarily flooded wetlands in the most disturbed areas within four Level IV ecoregions. The loss of temporarily flooded wetlands, in turn, means that there is

less habitat available in those disturbed areas than there may have been in the past. We also caution that this study should not be construed as indicating that human disturbance has negligible or no impacts on PPR wetlands across the landscape. Montana's "most disturbed" areas are still far less disturbed than areas to the east, where energy development, urbanization and agriculture are more widespread. We suggest that the current study demonstrates a sound and practical approach to measuring landscape level impacts on Prairie Pothole wetlands, and we encourage other researchers to undertake a similar analysis of wetlands in the more eastern portions of the PPR.

## Introduction

In the Prairie Pothole Region of Montana, wetland hydrologic diversity is closely linked to biotic diversity (Vance et al. 2013). At broad spatial and temporal scales, changes in water regimes due to drought and climate cycles drive avian, macroinvertebrate and fish distribution, with drought and flood cycles altering abundance and community structure, respectively decreasing and increasing available habitat by changing the areal extent of wetland and stream features. At the watershed level, however, impacts of this variability can be offset by the degree to which different water regimes are represented. In drought years, wetlands with more permanent water provide refugia for species whose usual habitats have dried up; similarly, in fluvial periods, otherwise ephemeral wetlands may replicate the short-term flooding on which other species rely (Kahara et al. 2009; Shaw et al. 2012).

In contrast to the temporal hydrologic variability in undisturbed wetlands, human manipulations of flood frequency, duration or extent in wetlands tend to be permanent, as are the changes in wetland function that they induce. For example, drained wetlands are effectively trapped in a permanent drought condition; similarly, shallow flow- through wetlands that are excavated and impounded will be flooded indefinitely. In the Prairie Pothole Region, agriculture is the driving force behind manipulation of hydrological conditions, which include tilling of shallow wetlands; excavation of wetlands to provide more permanent water storage; various forms of draining; dredging and channelization of intermittent and ephemeral streams; and impoundments of seasonal stream flows by dams or culverts. Energy development and associated infrastructure establishment, which have increased in recent years, also influence wetland hydrology, as do groundwater pumping for residential or industrial use, and impoundments for recreational use.

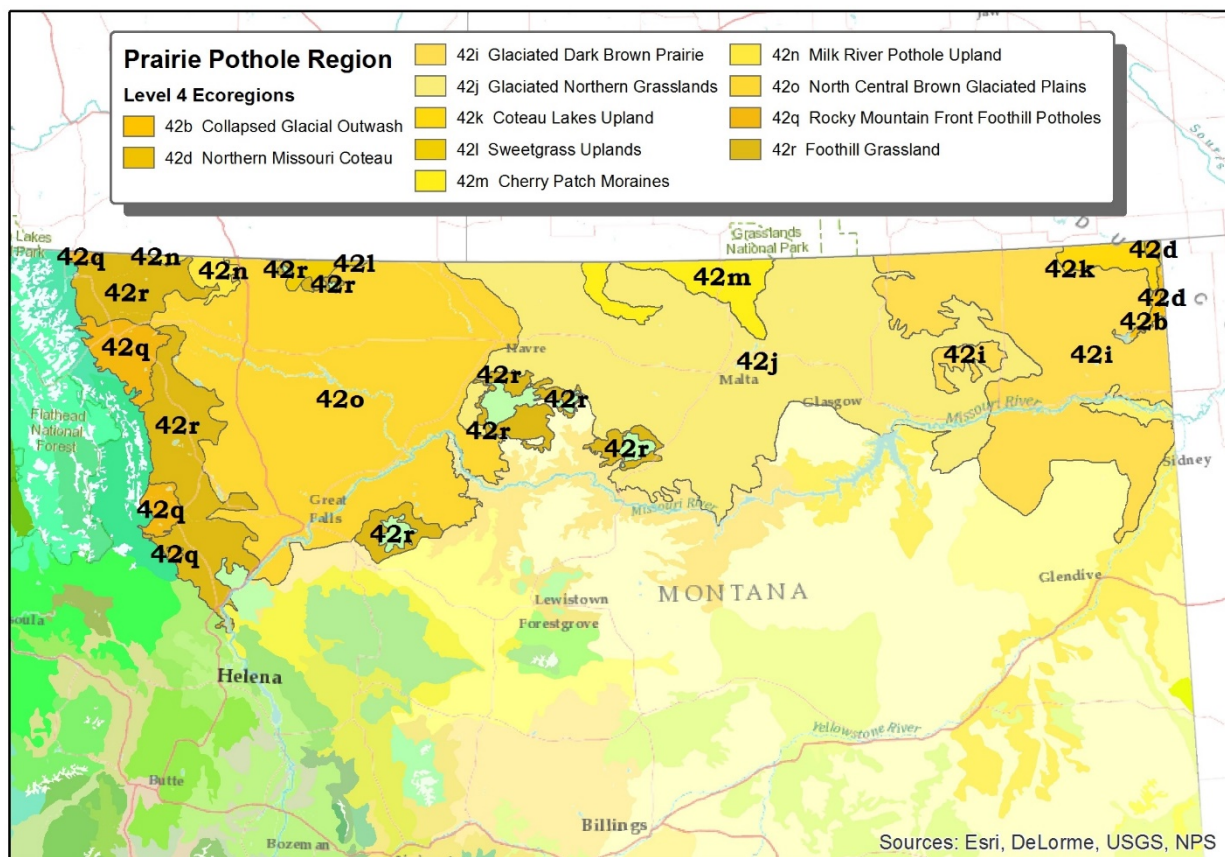
Because human disturbance tends to be clustered in particular areas, we have observed that wetland alteration is also more concentrated in some watersheds than in others, suggesting that landscape-level analysis of disturbance impacts plays an important role in wetland management. This is increasingly reflected in the literature. Whereas individual wetlands were once the main focus of research, in recent years attention has shifted to wetland complexes (Johnson & Werner 2010; Shaw et al. 2012). Wetland scientists and biologists now propose that individual wetlands in the Prairie Pothole Region may not be the appropriate units for evaluating the impacts of anthropogenic disturbance, except where the wetland is so large or so unique (e.g., certain alkaline lakes) that it is the only habitat feature of its kind in an area. Instead, it may be better to emphasize specific wetland landscape profiles as a target. In areas where human disturbance is minimal, wetland abundance, diversity of wetland types, and characteristic wetland size are linked to such landscape-level factors as geomorphology, basin hydrology, and regional or local climate (Johnson 2005). Consequently, similar landscapes might be expected to have similar wetland "profiles." These profiles in turn would help establish which wetland functions are associated with a particular region (e.g., subbasin, watershed, subwatershed), and could be the basis for management and/or restoration programs.



In this study, we build on earlier work using wetland profiles as part of wetland assessment in Montana (Vance et al. 2006; McIntyre et al. 2011; Newlon 2012) and Colorado (Lemly & Gilligan 2012). Our goal was to determine whether there are characteristic patterns of wetland abundance, size, and distribution of water regimes in relatively undisturbed landscapes, and assess whether these are significantly different from patterns in undisturbed areas.

## Methods

Our project area was the Prairie Pothole Region (PPR) of Montana. We defined that area as the portion of the Northwestern Glaciated Plains (Level 3 Ecoregion 42, Omernik 1987) that falls within Montana. Eleven Level 4 ecoregions are found within the area (Figure 1). In all, 384,778 wetland/riparian features are mapped in the PPR (Table 1).

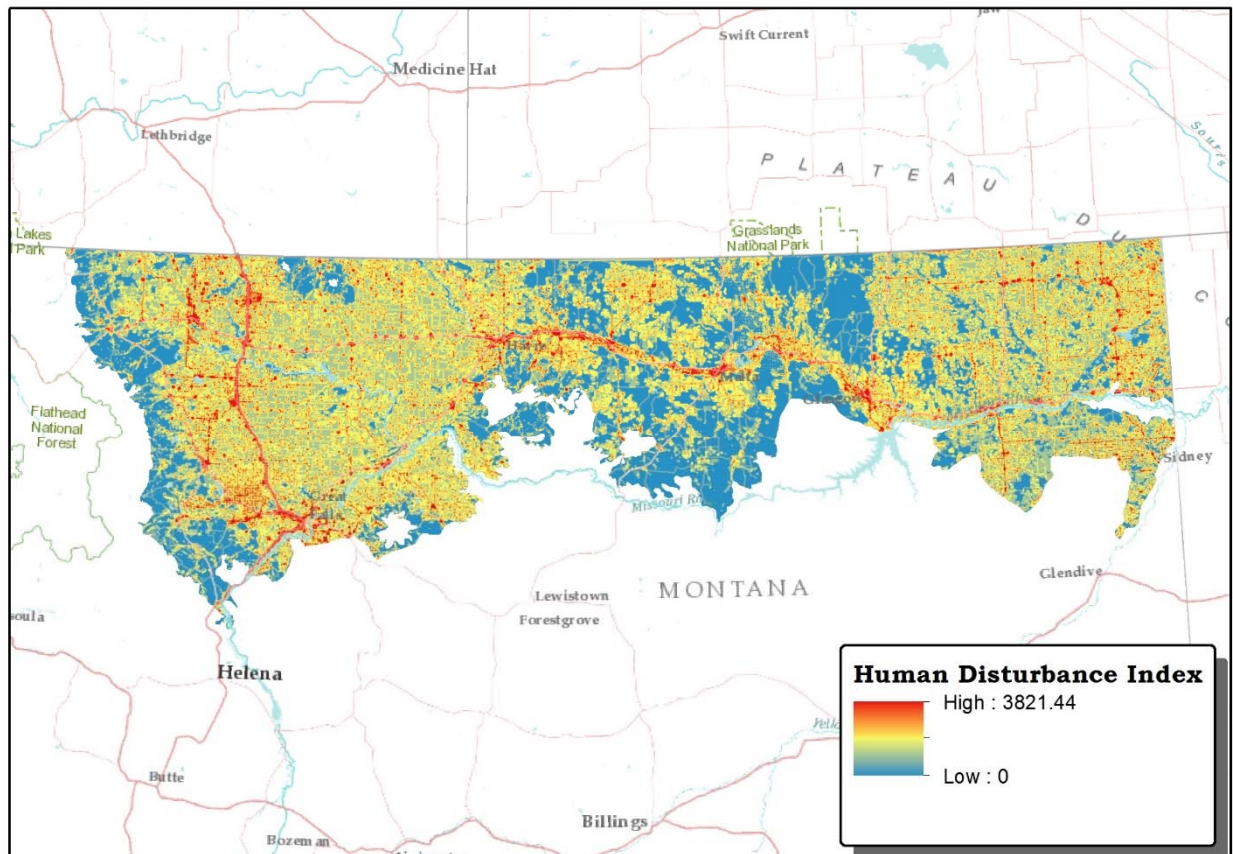


*Figure 1. Level 4 ecoregions in the Prairie Pothole Region of Montana.*

**Table 1.** Distribution of wetland/riparian features by Level 4 ecoregion.

Level 4 Ecoregion	# Patches	Hectares
42b Collapsed Glacial Outwash	2,609	8,503.57
42d Northern Missouri Coteau	1,983	2,002.56
42i Glaciated Dark Brown Prairie	64,254	59,444.65
42j Glaciated Northern Grasslands	143,900	122,163.30
42k Coteau Lakes Upland	12,310	7,063.24
42l Sweetgrass Uplands	5,168	3,024.90
42m Cherry Patch Moraines	36,380	18,191.27
42n Milk River Pothole Upland	4,910	2,528.98
42o North Central Brown Glaciated Plains	66,396	83,354.52
42q Rocky Mountain Front Foothill Potholes	12,440	16,458.95
42r Foothill Grassland	34,428	36,202.11
<b>Total</b>	<b>384,778</b>	<b>358,938.05</b>

To assess human disturbance in the Prairie Pothole Region, we used the Montana human disturbance index (HDI, MTNHP 2016). This raster index integrates six disturbance categories: development, transportation, agriculture, resource extraction/energy development, introduced vegetation, and forestry practices. HDI values in the PPR range from 0-3821.4, with larger values indicating higher levels of disturbance (Figure 2).

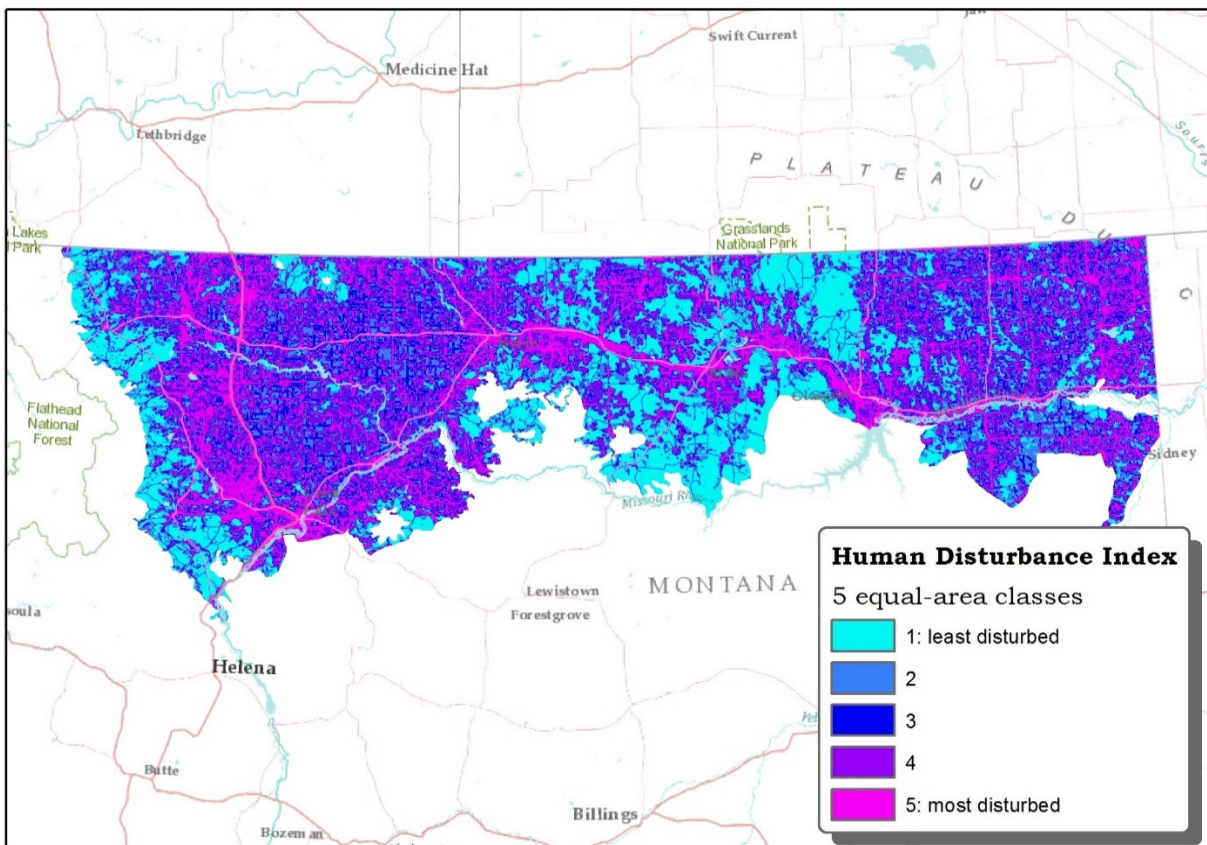


**Figure 2.** Human disturbance index (HDI) in the Prairie Pothole Region, Montana.

One of the inherent challenges in developing a landscape-level reference standard wetland profile is simply defining the landscape units for analysis. In our initial efforts, we looked at disturbance within sixth-code hydrologic units (HUC6s), but these units were too large; a single HUC6 could include areas of very high and very low disturbance. Catchments, on the other hand, were too small. Window frames of various sizes (4 x 4 sq mi, 10 x 10 sq mi) were problematic within the project area because the patterns of disturbance were widespread and variable enough that it was difficult to find sufficient areas with uniform disturbance within a frame, especially when also stratifying by Level 4 ecoregion. So we turned to the idea of letting the disturbance classes themselves define the analysis units.

First, we classified HDI into quintiles, each with approximately equal area (Figure 3, Tables 2 and 3):

1. 0-209.8
2. 209.8-629.4
3. 629.4-944.1
4. 944.1-1213.9
5. 1213.9-3821.4



**Figure 3.** Human disturbance index (HDI) in five equal-area classes for the Prairie Pothole Region, Montana.

**Table 2.** Human disturbance index (HDI) class by Level 4 ecoregion, showing the number of patches, total hectares, and percent of the ecoregion occupied by each class.

Level 4 Ecoregion	Human Disturbance Index															Total	
	Class 1 - Least Disturbed			Class 2			Class 3			Class 4			Class 5 - Most Disturbed				
	Patches	Ha	% L4	Patches	Ha	% L4	Patches	Ha	% L4	Patches	Ha	% L4	Patches	Ha	% L4		Patches
Cherry Patch Moraines	113	85,374	35.30	341	54,902	22.70	371	33,298	13.77	322	43,711	18.07	265	24,489	10.13	1,412	241,774
Collapsed Glacial Outwash	13	5,875	19.14	44	5,794	18.87	53	6,533	21.28	53	5,156	16.80	55	7,243	23.59	218	30,600
Coteau Lakes Upland	37	3,019	3.01	137	18,103	18.05	73	31,078	30.98	91	21,506	21.44	147	26,339	26.26	485	100,044
Foothill Grassland	519	397,404	35.30	799	274,254	24.36	1,106	156,102	13.87	889	143,941	12.79	747	153,535	13.64	4,060	1,125,237
Glaciated Dark Brown Prairie	740	129,073	7.21	1,864	394,471	22.04	1,108	474,776	26.53	1,530	381,110	21.30	1,968	409,689	22.89	7,210	1,789,119
Glaciated Northern Grasslands	944	1,051,350	35.19	1,476	597,707	20.01	2,294	380,003	12.72	1,822	511,476	17.12	1,680	446,667	14.95	8,216	2,987,204
Milk River Pothole Upland	35	7,875	11.76	85	11,767	17.57	107	13,414	20.02	118	15,153	22.62	128	18,679	27.88	473	66,888
N. Central Brown Glaciated Plains	530	91,133	3.11	2,817	493,109	16.80	2,394	782,364	26.66	2,057	768,028	26.17	2,903	800,101	27.26	10,701	2,934,733
Northern Missouri Coteau	5	339	2.77	13	2,516	20.58	22	2,344	19.18	25	2,287	18.71	12	4,573	37.42	77	12,058
Rocky Mtn Front Foothill Potholes	127	131,709	52.81	108	70,374	28.22	168	23,767	9.53	159	12,409	4.98	88	10,967	4.40	650	249,226
Sweetgrass Uplands	48	15,943	34.17	62	13,714	29.40	72	6,298	13.50	55	5,174	11.09	48	5,446	11.67	285	46,576
Total	3,111	1,919,095		7,746	1,936,709		7,768	1,909,975		7,121	1,909,952		8,041	1,907,728		33,787	9,583,459



**Table 3.** Patch size statistics for Human Disturbance Index (HDI) classes by Level 4 ecoregion for the Prairie Pothole Region, Montana.

Level 4 Ecoregion												
HDI	Patch Size	Cherry	Collapsed	Coteau		Glaciated		Milk R.	N. Central	N.	Rocky	
		Patch	Glacial	Lakes	Foothill	Dk Brown	Glaciated N.	Pothole	Brown	Missouri	Mtn Front	Sweetgrass
		Moraines	Outwash	Upland	Grassland	Prairie	Grasslands	Upland	Glaciated Plains	Coteau	Potholes	Uplands
Class 1 (Least Disturbed)	Mean	755.53	451.90	81.59	765.71	174.42	1,113.72	225.00	171.95	67.78	1,037.08	332.15
	Std Dev	2,152.22	1,057.09	127.01	2,019.91	584.92	4,639.07	478.52	535.50	136.80	2,759.45	929.84
	Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.06	0.00
	Max	10,823.85	3,878.02	628.74	18,074.56	6,992.37	80,730.32	1,888.38	6,284.52	312.48	15,386.58	5,478.90
Class 2	Mean	161.00	131.67	132.14	343.25	211.63	404.95	138.43	175.05	193.52	651.61	221.19
	Std Dev	1,455.78	361.19	327.66	2,886.17	1,264.54	5,392.54	379.13	591.75	291.07	3,576.92	1,087.35
	Min	0.00	0.07	0.00	0.00	0.00	0.00	0.09	0.00	0.99	0.00	0.00
	Max	26,192.16	2,133.83	1,923.48	46,333.88	38,253.22	174,443.87	2,675.59	15,422.31	835.27	32,658.99	8,055.92
Class 3	Mean	89.75	123.26	425.72	141.14	428.50	165.65	125.37	326.80	106.53	141.47	87.47
	Std Dev	348.24	371.02	1,886.71	832.29	5,638.72	1,739.62	428.18	3,681.17	225.69	413.65	286.25
	Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Max	5,148.82	1,953.65	12,594.29	18,157.90	166,572.30	60,660.59	3,315.69	116,654.94	1,019.30	5,008.92	2,119.69
Class 4	Mean	135.75	97.28	236.33	161.91	249.09	280.72	128.41	373.37	91.48	78.04	94.08
	Std Dev	573.77	225.17	631.37	1,325.68	2,308.02	3,209.08	955.60	9,736.28	175.73	167.71	266.16
	Min	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Max	8,087.17	1,306.76	5,335.81	32,464.84	77,540.84	108,990.92	10,369.76	437,574.69	746.72	1,660.86	1,764.03
Class 5 (Most Disturbed)	Mean	92.41	131.69	179.18	205.54	208.18	265.87	145.93	275.61	381.07	124.63	113.46
	Std Dev	267.32	219.35	405.03	1,028.95	959.30	3,119.96	425.40	4,162.18	892.42	266.84	307.12
	Min	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.54	0.00	0.63
	Max	2,731.84	1,123.85	3,274.09	21,149.78	32,572.88	96,539.06	3,019.14	211,507.15	3,151.04	2,015.28	2,028.51

Results were then converted to vector polygons to identify contiguous blocks of each disturbance class. We examined polygons  $\geq 5000$  ha of disturbance class 1 (least disturbed) and classes 4 and 5 (most disturbed) within each ecoregion (Tables 4 and 5).

Within six Level 4 ecoregions, we selected 29 paired analysis units representing least and most disturbed landscapes (Figure 4, Table 6). Each unit was at least 5000 ha in size. We matched pairs as closely as possible in terms of their size. Two ecoregions, Glaciated Northern Grasslands and Foothill Grassland, had very large patches of most disturbed habitat; we subset these patches to match the largest patches of least disturbed habitat in those ecoregions. We made one exception to the 5000 ha size limit for the Rocky Mountain Front Foothill Potholes ecoregion. There, the largest contiguous patches of most disturbed habitat were 2794 and 4294 ha; we paired these patches with the two smallest patches of least disturbed habitat (5787 and 6756 ha). Glaciated Northern Grasslands is by far the best represented ecoregion, with 15 of the 29 pairs and nearly 70% of the total hectares selected for analysis.

**Table 4.** Seven of the eleven Level 4 ecoregions contain patches of least disturbed habitat (HDI class = 1) that are at least 5000 ha in size.

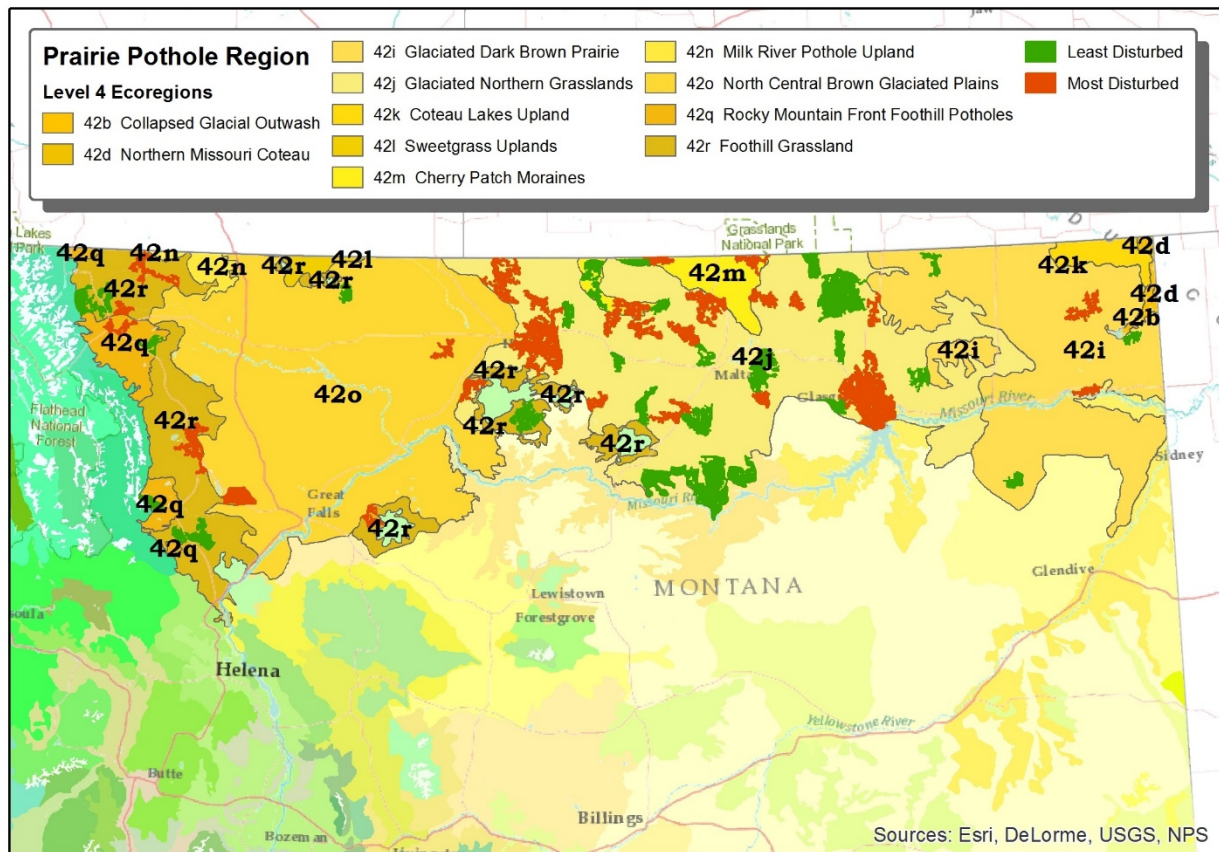
Level 4 Ecoregion		# Patches	Hectares
42i	Glaciated Dark Brown Prairie	3	18,323.78
42j	Glaciated Northern Grasslands	49	737,214.12
42l	Sweetgrass Uplands	1	5,478.90
42m	Cherry Patch Moraines	9	69,869.80
42o	North Central Brown Glaciated Plains	1	6,284.52
42q	Rocky Mountain Front Foothill Potholes	9	89,506.06
42r	Foothill Grassland	31	233,223.30
<b>Total</b>		<b>103</b>	<b>1,159,900.50</b>

**Table 5.** Seven of the eleven Level 4 ecoregions have contiguous patches of disturbed habitat (HDI classes 4 and 5) that are at least 5000 ha in size.

Level 4 Ecoregion		# Patches	Hectares
42i	Glaciated Dark Brown Prairie	11	497,286.07
42j	Glaciated Northern Grasslands	15	677,471.28
42k	Coteau Lakes Upland	1	23,308.51
42m	Cherry Patch Moraines	3	25,750.65
42n	Milk River Pothole Upland	1	27,252.71
42o	North Central Brown Glaciated Plains	5	1,280,303.03
42r	Foothill Grassland	5	179,995.13
<b>Total</b>		<b>41</b>	<b>2,711,367.38</b>

Five of the eleven ecoregions lacked sufficiently large patches of least disturbed, most disturbed, or both, and thus were excluded from analysis. These are: Collapsed Glacial

Outwash, Northern Missouri Coteau, Coteau Lakes Upland, Sweetgrass Uplands, and Milk River Pothole Upland. All five of these are along the state border and are of limited extent in Montana.



**Figure 4.** Paired analysis units, showing least disturbed units in green and most disturbed units in red.

**Table 6.** Paired analysis units in six Level 4 ecoregions.

Level 4 Ecoregion		# PAIRS	TOTAL HECTARES	
			Least Disturbed	Most Disturbed
42i	Glaciated Dark Brown Prairie	3	18,324	18,166
42j	Glaciated Northern Grasslands	15	278,070	278,241
42m	Cherry Patch Moraines	3	23,856	25,751
42o	North Central Brown Glaciated Plains	1	6285	6288
42q	Rocky Mountain Front Foothill Potholes	2	12,543	7088
42r	Foothill Grassland	5	59,380	59,601
<b>Total</b>		<b>29</b>	<b>398,300</b>	<b>395,293</b>

We selected wetland/riparian features that fell completely within the analysis units; the least disturbed units held 16,163 features, and the most disturbed units had 20,543 features. Then we summarized wetland types (Table 7), water flow paths (Table 8), number of altered wetlands as indicated by special modifiers (Table 9), and water regimes (Table 10). We also calculated summary statistics for wetland size (Table 11) and density (Table 12), distance between wetland centroids (Table 13), and number of landscape complexes (Table 14) and wetland mosaics (Table 15).

## Results

*Wetland types and water paths.* We saw few obvious differences between wetland types for least disturbed and most disturbed landscapes (Table 7). Where glaring discrepancies occurred, as with riverine features in the Glaciated Northern Grasslands (149 features in undisturbed landscapes versus 1584 in disturbed landscapes), we surmise that this is not a result of the disturbance, but rather the reason the disturbance exists in the first place: areas closer to running water and floodplains are the most likely to be settled. Presumably, the riverine features in this part of the Grasslands existed before European settlement occurred. This also explains the notable difference in number of patches having a “throughflow” water path in the most disturbed parts of the Glaciated Northern Grasslands (Table 8): there is simply a greater areal extent of perennial lotic systems.

*Alteration.* Disturbance patterns are, however, reflected in the degree of alteration to wetland features. In all but one ecoregion, the percentage of unaltered wetlands was higher in least disturbed landscapes than it was in most disturbed ones (Table 9). Of the alterations, farming appears to be the most common. We note here that small impoundments are common in both kinds of landscapes. Although measurable human impacts like roads, agriculture and structures are less frequent in least disturbed areas, grazing is a common use, and wetlands are often excavated, enhanced or created to provide stock watering year round. Consequently, in some ecoregions (42i, 42j and 42q), the percent of diked/impounded wetland hectares is similar across the impact gradient. In the Cherry Patch Moraines and North Central Brown Glaciated Plains, however, more than twice as many hectares are diked/impounded in the most disturbed areas.

Water permanence appears to be loosely correlated with alteration in most ecoregions (Table 10 and Figures 5 and 6). In least disturbed landscapes, alterations tend to be associated with the “F” (semi-permanently flooded) water regime. Least disturbed landscapes in the PPR are often open to cattle grazing (which, because of the absence of spatial data, is not picked up as a direct disturbance in our analysis), which requires access to water. Consequently, we would expect that some of the wettest wetlands would be enhanced by diking, damming or excavation to meet this need. In the most disturbed areas, while “F” regimes are also often associated with alteration, we see a much higher percentage of temporarily flooded wetlands being altered. These reflect the impacts of direct land-use alteration, such as road building, agriculture, and energy development,



which often intersect these drier wetlands. Not surprising, the areas where “A” water regimes are less altered are the foothills of the Rocky Mountains at the very western edge of the study area, where the terrain does not lend itself to extensive road-building or to irrigated agriculture, and where oil and gas development is less widespread.

However, it seems likely that much of the alteration that has occurred is not directly detectable through map analysis. In short, wetland loss is not easily measured; we can only characterize how the remaining wetlands differ in terms of their size, distribution and water regime. All the same, the data strongly suggest that significant wetland loss has occurred. In Figures 5 and 6, we can see considerable differences in the percentage of temporarily flood wetlands (both by number and by area) between least disturbed and most disturbed areas, with lower percentages occurring in least disturbed areas. While it would require analysis of historical photographs (or field verification) to form final conclusions, we can infer that many of the drier wetlands have simply been lost over time as the human footprint has spread.

*Density.* Wetland density does not vary greatly across the study area, except in the Cherry Patch Moraine ecoregion, which is characterized by high pothole numbers (Table 12). Nor did we observe large differences between density in most and least disturbed areas, with the notable exception of the Rocky Mountain Front Foothills pothole ecoregion, where wetland density is almost twice as high in disturbed regions. Some of this is attributable to the particular geology and geography of the area, where wetland distribution tends to be concentrated on the edge of glacial moraines, but there are also several very large reservoirs. Because density is calculated as hectares of wetlands per hectare of land area, these reservoirs skew the density results.

*Wetland complexes.* The occurrence of wetland complexes (in essence, areas where wetlands tend to occur in close proximity, but separated by uplands) does not follow a clear pattern (Table 14). Complexes are more prevalent in least disturbed areas in some ecoregions, and in most disturbed areas in others. In the case, it does not appear that disturbance is a predictive factor. After all, disturbances in the Montana portion of the PPR are neither highly concentrated nor especially large in extent; most are “tucked in” to the upland areas surrounding wetlands without necessarily affecting the distribution of wetland features.

*Wetland mosaics.* Wetland mosaics (aggregations of intersection or adjacent wetlands) were difficult to summarize by analysis area because (especially for riverine and floodplain systems) mosaics tend to be long and linear. Selecting mosaics that fall entirely within analysis units would skew results toward the smallest mosaics; on the other hand, selecting mosaics that intersect analysis units (as we did) leads to sizeable portions of mosaics that are far outside the borders of the analysis units. And in some cases, mosaics intersect more than one analysis unit and/or ecoregion, complicating the picture. For these reasons, we simply contrast wetland mosaics for least disturbed and most disturbed landscapes (Table 15). Although there are fewer wetland mosaics in the least disturbed landscapes, those mosaics tend to be composed of greater numbers of wetlands and to occupy more area. It is worth noting that one wetland mosaic along Fort Peck Reservoir, comprised of 10,815 features, is so large that it intersects two analysis units separated by about 85 km. Because one of those analysis units is least disturbed and the other most disturbed, this mosaic sets the maximum values for both.

## Discussion

Overall, we did not find strong evidence that characteristic patterns of wetland abundance, size, and distribution are linked to disturbance in the areas we studied, although we did note that there appears to have been a loss of temporarily flooded wetlands in the most disturbed areas within Level IV ecoregions 42i, 42j, 42o and 42q. The loss of temporarily flooded wetlands, in turn, means that there is less habitat available in those disturbed areas than there may have been in the past. This pattern, which has been noted in other areas of the PPR, should be monitored by land and wildlife managers going forward.

Nothing in this study should be construed as indicating that human disturbance has negligible or no impacts on PPR wetlands across the landscape. Montana's "most disturbed" areas are still far less disturbed than areas to the east, where energy development, urbanization and agriculture are more widespread.

Similarly, the areas of Montana's PPR that are characterized by a GIS as "least disturbed" are not undisturbed; as noted above, these are areas where livestock grazing tends to be the primary land use. While livestock grazing does not necessarily bring about changes in wetland abundance, size or distribution, it can have considerable impacts on wetland ecological integrity. Subsequent analyses would ideally incorporate field-based studies of wetland condition to determine whether wetlands in least disturbed areas are significantly more "healthy" than those surrounded by disturbance.

For now, however, we believe that the current study demonstrates a sound and practical approach to measuring landscape level impacts on Prairie Pothole wetlands, and we encourage other researchers to undertake a similar analysis of wetlands in the more eastern portions of the PPR.

**Table 7.** Types of wetland/riparian features in least disturbed and most disturbed landscapes for six Level 4 ecoregions in the Prairie Pothole Region of Montana.

			# Wetlands		Hectares		% Area	
Level 4 Ecoregion		Wetland Type	Least	Most	Least	Most	Least	Most
42i	Glaciated Dark Brown Prairie	Depressional Wetland	0	11	0	2.31	0.00%	0.55%
		Floodplain and Riparian	196	173	165.01	72.11	43.91%	17.13%
	Freshwater Emergent Wetland	339	284	87.90	210.68	23.39%	50.06%	
	Freshwater Forested/Shrub Wetland	1	5	0.20	2.81	0.05%	0.67%	
	Freshwater Pond	48	85	11.43	27.74	3.04%	6.59%	
	Other	3	0	0.37	0.00	0.10%	0.00%	
	Riparian Emergent	95	49	94.04	42.31	25.02%	10.05%	
	Riparian Forested	6	43	4.55	38.08	1.21%	9.05%	
	Riparian Scrub-Shrub	0	24	0.00	19.22	0.00%	4.57%	
	Riverine	19	15	12.29	5.64	3.27%	1.34%	
Total		707	689	375.79	420.89	100.00%	100.00%	
42j	Glaciated Northern Grasslands	Depressional Wetland	5	30	0.79	17.67	0.02%	0.22%
		Floodplain and Riparian	337	1,062	225.39	640.64	4.43%	8.16%
		Freshwater Emergent Wetland	4,915	5,579	2,508.61	3,330.06	49.26%	42.39%
		Freshwater Forested/Shrub Wetland	63	141	22.85	60.66	0.45%	0.77%
		Freshwater Pond	2,241	1,998	1,252.57	800.63	24.60%	10.19%
		Herbaceous Marsh	1	42	0.09	35.28	0.00%	0.45%
		Lake	13	21	138.71	333.91	2.72%	4.25%
		Open Water	0	591	0.00	78.89	0.00%	1.00%
		Other	0	531	0.00	238.31	0.00%	3.03%
		Riparian Emergent	1,150	1,018	665.30	560.94	13.06%	7.14%
		Riparian Forested	246	321	113.41	250.57	2.23%	3.19%
		Riparian Scrub-Shrub	96	936	38.60	386.49	0.76%	4.92%
		Riverine	149	1,584	114.12	847.27	2.24%	10.79%
		Swamp/Marsh	0	5	0.00	6.12	0.00%	0.08%
		Wet meadow	22	516	12.35	268.31	0.24%	3.42%
Total		9,238	14,375	5,092.79	7,855.75	100.00%	100.00%	
42m	Cherry Patch Moraines	Freshwater Emergent Wetland	3,854	2,958	1,322.25	1,567.21	95.28%	95.05%
		Freshwater Pond	128	185	58.40	78.20	4.21%	4.74%
		Riparian Emergent	7	5	2.81	2.23	0.20%	0.14%
		Riparian Forested	0	5	0.00	0.54	0.00%	0.03%
		Riverine	4	3	4.33	0.64	0.31%	0.04%
Total		3,993	3,156	1,387.80	1,648.81	100.00%	100.00%	

**Table 7 (continued).** Types of wetland/riparian features in least disturbed and most disturbed landscapes for six Level 4 ecoregions in the Prairie Pothole Region of Montana.

Level 4 Ecoregion		Wetland Type	# Wetlands		Hectares		% Area	
			Least	Most	Least	Most	Least	Most
42o	North Central Brown Glaciated Plains	Floodplain and Riparian	0	35	0.00	22.40	0.00%	19.75%
		Freshwater Emergent Wetland	88	86	28.69	35.68	32.75%	31.45%
		Freshwater Forested/Shrub Wetland	0	2	0.00	0.57	0.00%	0.51%
		Freshwater Pond	29	50	5.59	8.53	6.38%	7.52%
		Lake	0	3	0.00	21.45	0.00%	18.91%
		Other	50	3	5.33	0.91	6.08%	0.80%
		Riparian Emergent	14	1	7.23	0.21	8.25%	0.19%
		Riparian Forested	0	1	0.00	0.07	0.00%	0.06%
		Riparian Scrub-Shrub	0	5	0.00	1.63	0.00%	1.43%
		Riverine	3	5	2.10	1.66	2.40%	1.46%
		Swamp/Marsh	1	0	0.02	0.00	0.03%	0.00%
		Wet meadow	119	10	38.63	20.32	44.10%	17.92%
		Total	304	201	87.59	113.43	100.00%	100.00%
42q	Rocky Mountain Front Foothill Potholes	Bog or Fen	2	0	0.54	0.00	0.24%	0.00%
		Depressional Wetland	10	2	13.52	5.22	6.00%	1.39%
		Floodplain and Riparian	40	39	23.55	50.42	10.46%	13.45%
		Freshwater Emergent Wetland	132	198	86.01	265.83	38.19%	70.90%
		Freshwater Forested/Shrub Wetland	19	0	17.55	0.00	7.79%	0.00%
		Freshwater Pond	39	46	12.15	45.88	5.39%	12.24%
		Herbaceous Marsh	0	1	0.00	2.58	0.00%	0.69%
		Lake	2	0	14.90	0.00	6.62%	0.00%
		Open Water	2	0	0.18	0.00	0.08%	0.00%
		Other	58	7	50.08	3.28	22.23%	0.88%
		Riverine	14	0	6.76	0.00	3.00%	0.00%
		Wet meadow	0	7	0.00	1.73	0.00%	0.46%
		Total	318	300	225.25	374.94	100.00%	100.00%
42r	Foothill Grassland	Bog or Fen	0	1	0.00	0.17	0.00%	0.01%
		Depressional Wetland	17	33	22.29	12.39	2.01%	0.85%
		Floodplain and Riparian	491	685	617.29	577.26	55.67%	39.50%
		Freshwater Emergent Wetland	283	395	110.82	435.80	9.99%	29.82%
		Freshwater Forested/Shrub Wetland	92	109	179.01	210.95	16.14%	14.43%
		Freshwater Pond	585	218	102.01	53.56	9.20%	3.66%
		Herbaceous Marsh	0	37	0.00	33.19	0.00%	2.27%
		Lake	1	3	19.12	11.60	1.72%	0.79%
		Open Water	0	183	0.00	24.30	0.00%	1.66%
		Other	32	51	11.44	37.43	1.03%	2.56%
		Riparian Emergent	26	0	10.66	0.00	0.96%	0.00%
		Riparian Forested	9	0	3.59	0.00	0.32%	0.00%
		Riparian Scrub-Shrub	13	0	5.97	0.00	0.54%	0.00%
		Riverine	27	118	18.51	64.75	1.67%	4.43%
		Wet Meadow	27	0	8.20	0.00	0.74%	0.00%
		Total	1,603	1,833	1,108.92	1,461.41	100.00%	100.00%

**Table 8.** Water flow paths assigned to wetland/riparian features contrasted for least disturbed and most disturbed landscapes for six Level 4 ecoregions in the Prairie Pothole Region of Montana.

Level 4 Ecoregion		Flow Path	Least Disturbed		Most Disturbed	
			# Patches	Hectares	# Patches	Hectares
42i	Glaciated Dark Brown Prairie	Inflow	4	0.48	6	0.60
		Inflow Artificial	0	0.00	4	2.22
		Outflow	3	2.60	0	0.00
		Throughflow	479	327.37	464	275.32
		Vertical Flow	181	35.07	191	107.09
		Vertical Flow Complex	40	10.26	31	35.79
42j	Glaciated Northern Grasslands	Bidirectional Flow	15	112.45	15	33.34
		Bidirectional, Artificial	44	23.38	58	23.37
		Inflow	181	21.68	282	279.44
		Inflow Artificial	1	0.06	29	25.17
		Outflow	25	26.65	23	15.33
		Throughflow	6470	3,945.63	10068	5,338.64
		Vertical Flow	1927	539.50	2939	1,331.27
		Vertical Flow Complex	598	432.03	1015	815.95
42m	Cherry Patch Moraines	Inflow	24	2.97	42	5.96
		Inflow Artificial	0	0.00	2	0.06
		Outflow	3	1.92	1	0.02
		Throughflow	274	184.12	439	452.14
		Vertical Flow	1906	393.13	1544	505.19
		Vertical Flow Complex	1844	818.31	1135	686.56
42o	North Central Brown Glaciated Plains	Bidirectional Flow	0	0.00	6	1.70
		Bidirectional, Artificial	0	0.00	5	1.11
		Inflow	1	0.02	1	0.74
		Throughflow	96	46.28	121	86.70
		Vertical Flow	157	23.98	59	21.28
		Vertical Flow Complex	50	17.31	9	1.91
42q	Rocky Mountain Front Foothill Potholes	Bidirectional Flow	1	2.01	0	0.00
		Inflow	0	0.00	11	3.41
		Outflow	2	2.20	3	3.73
		Throughflow	244	196.18	121	269.10
		Vertical Flow	48	15.99	125	55.49
		Vertical Flow Complex	23	8.86	40	43.21
42r	Foothill Grassland	Bidirectional Flow	5	1.40	3	20.66
		Bidirectional, Artificial	0	0.00	3	2.35
		Inflow	4	0.23	5	2.29
		Inflow Artificial	0	0.00	10	6.55
		Outflow	10	6.25	3	0.89
		Throughflow	1395	1,054.51	1458	1,250.12
		Vertical Flow	183	41.89	309	122.99
		Vertical Flow Complex	6	4.64	42	55.55

**Table 9.** Special modifiers assigned to wetland/riparian features in least disturbed and most disturbed landscapes for six Level 4 ecoregions in the Prairie Pothole Region of Montana.

Level 4 Ecoregion		Modifier	# Wetlands		Hectares		% Area	
			Least	Most	Least	Most	Least	Most
42i	Glaciated Dark Brown Prairie	(none)	658	544	361.60	310.67	96.22%	73.81%
		Partly drained/ditched	0	2	0.00	2.67	0.00%	0.63%
		Farmed	1	45	0.17	75.62	0.05%	17.97%
		Diked/impounded	41	58	12.54	15.73	3.34%	3.74%
		Excavated	7	40	1.48	16.20	0.39%	3.85%
	Total		707	689	375.79	420.89	100.00%	100.00%
42j	Glaciated Northern Grasslands	(none)	6,537	9,327	3,835.85	4,952.64	75.32%	63.04%
		Beaver	6	204	0.98	26.87	0.02%	0.34%
		Partly drained/ditched	2	11	2.89	32.64	0.06%	0.42%
		Farmed	4	1,124	0.19	772.22	0.00%	9.83%
		Diked/impounded	2,365	2,886	1,213.42	1,619.00	23.83%	20.61%
		Excavated	324	823	39.46	452.37	0.77%	5.76%
	Total		9,238	14,375	5,092.79	7,855.75	100.00%	100.00%
42m	Cherry Patch Moraines	(none)	3,804	1,458	1,316.30	689.45	94.85%	41.81%
		Partly drained/ditched	0	7	0.00	15.62	0.00%	0.95%
		Farmed	0	1,318	0.00	758.14	0.00%	45.98%
		Diked/impounded	111	239	61.79	169.71	4.45%	10.29%
		Excavated	78	134	9.71	15.89	0.70%	0.96%
	Total		3,993	3,156	1,387.80	1,648.81	100.00%	100.00%
42o	North Central Brown Glaciated Plains	(none)	254	155	75.41	63.65	86.10%	56.11%
		Partly drained/ditched	0	1	0.00	2.22	0.00%	1.96%
		Farmed	0	9	0.00	11.84	0.00%	10.44%
		Diked/impounded	44	32	11.73	34.52	13.40%	30.43%
		Excavated	6	4	0.44	1.20	0.51%	1.06%
	Total		304	201	87.59	113.43	100.00%	100.00%
42q	Rocky Mountain Front Foothill Potholes	(none)	285	270	221.98	359.35	98.55%	95.84%
		Beaver	26	0	1.94	0.00	0.86%	0.00%
		Partly drained/ditched	0	1	0.00	0.85	0.00%	0.23%
		Diked/impounded	7	6	1.32	6.34	0.59%	1.69%
		Excavated	0	23	0.00	8.39	0.00%	2.24%
	Total		318	300	225.25	374.94	100.00%	100.00%
42r	Foothill Grassland	(none)	984	1,582	1,004.87	1,383.01	90.62%	94.64%
		Beaver	521	79	76.23	11.72	6.87%	0.80%
		Diked/impounded	93	121	27.53	33.89	2.48%	2.32%
		Excavated	5	51	0.30	32.80	0.03%	2.24%
	Total		1,603	1,833	1,108.92	1,461.41	100.00%	100.00%

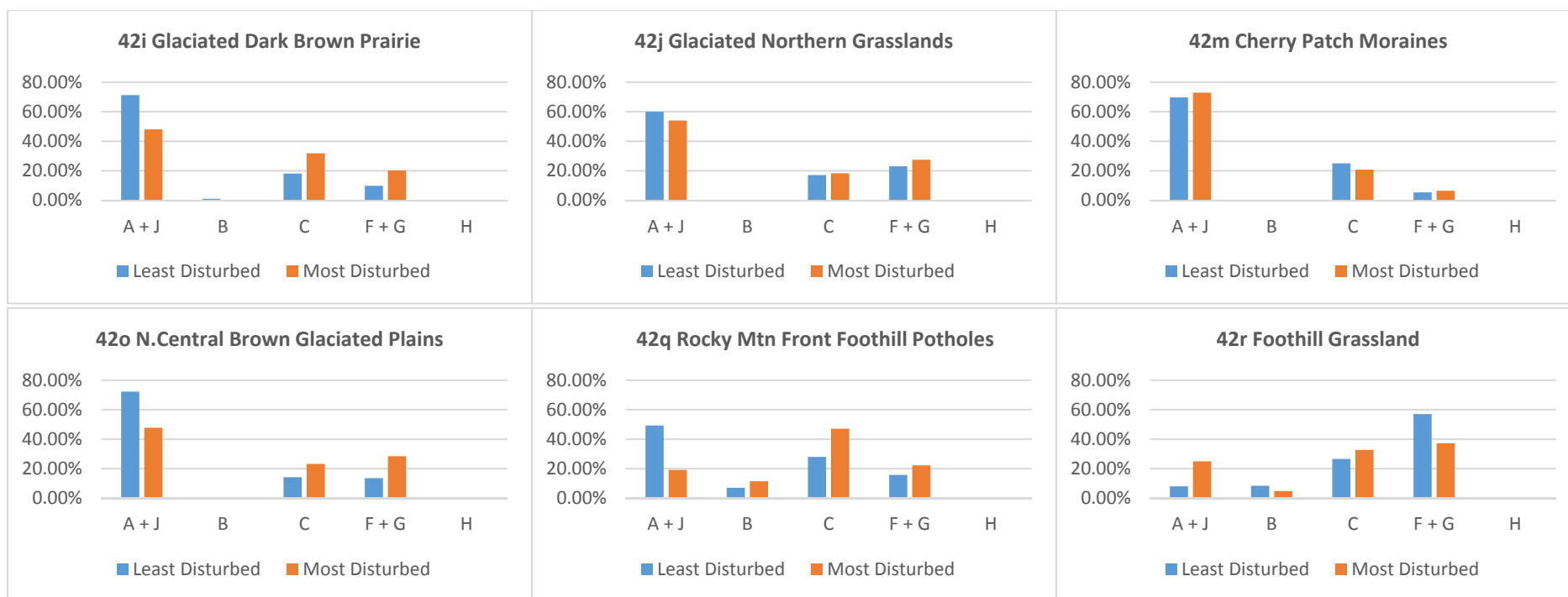
**Table 10.** Water regimes for altered and unaltered wetland-riparian features in least disturbed and most disturbed landscapes for six Level 4 ecoregions in the Prairie Pothole Region of Montana. Altered wetland features are those with special modifiers “d” (partly drained/ditched), “f” (farmed), “h” (diked/impounded), and “x” (excavated); all others were treated as unaltered. Water regimes: A = temporarily flooded; B = saturated; C = seasonally flooded; E = seasonally flooded/saturated; F = semipermanently flooded; G = intermittently exposed; H = permanently flooded; J = intermittently flooded; K = artificially flooded. Note that riparian polygons are not assigned water regimes.

Level 4 Ecoregion Water Regime	# Wetlands				% of Wetlands				Hectares			
	Least Disturbed		Most Disturbed		Least Disturbed		Most Disturbed		Least Disturbed		Most Disturbed	
	Altered	Unaltered	Altered	Unaltered	Altered	Unaltered	Altered	Unaltered	Altered	Unaltered	Altered	Unaltered
<b>42i Glaciated Dark Brown Prairie</b>	<b>49</b>	<b>658</b>	<b>145</b>	<b>544</b>	<b>6.93%</b>	<b>93.07%</b>	<b>21.04%</b>	<b>78.96%</b>	<b>14.19</b>	<b>361.60</b>	<b>110.21</b>	<b>310.67</b>
A	17	219	72	116	2.40%	30.98%	10.45%	16.84%	5.35	66.79	52.17	69.45
B	0	4	0	0	0.00%	0.57%	0.00%	0.00%	0.00	2.49	0.00	0.00
C	9	65	20	106	1.27%	9.19%	2.90%	15.38%	1.77	16.28	32.75	44.95
F	21	17	45	31	2.97%	2.40%	6.53%	4.50%	6.57	4.22	19.76	23.90
G	2	0	4	0	0.28%	0.00%	0.58%	0.00%	0.50	0.00	3.31	0.00
J	0	56	0	2	0.00%	7.92%	0.00%	0.29%	0.00	8.21	0.00	0.65
K	0	0	4	0	0.00%	0.00%	0.58%	0.00%	0.00	0.00	2.22	0.00
(Riparian)	0	297	0	289	0.00%	42.01%	0.00%	41.94%	0.00	263.60	0.00	171.71
<b>42j Glaciated N. Grasslands</b>	<b>2,695</b>	<b>6,543</b>	<b>4,844</b>	<b>9,531</b>	<b>29.17%</b>	<b>70.83%</b>	<b>33.70%</b>	<b>66.30%</b>	<b>1,255.96</b>	<b>3,836.83</b>	<b>2,876.24</b>	<b>4,979.51</b>
A	794	3,433	2,234	3,023	8.59%	37.16%	15.54%	21.03%	364.07	2,013.72	1,243.76	1,741.73
B	0	7	0	18	0.00%	0.08%	0.00%	0.13%	0.00	0.71	0.00	6.17
C	529	733	857	996	5.73%	7.93%	5.96%	6.93%	218.18	465.66	451.10	496.86
F	1,358	332	1,651	1,129	14.70%	3.59%	11.49%	7.85%	625.69	59.91	794.86	268.02
G	11	0	7	2	0.12%	0.00%	0.05%	0.01%	47.14	0.00	20.96	1.89
H	0	0	4	10	0.00%	0.00%	0.03%	0.07%	0.00	0.00	276.30	14.88
J	2	209	57	182	0.02%	2.26%	0.40%	1.27%	0.81	254.13	37.81	114.72
K	1	0	29	0	0.01%	0.00%	0.20%	0.00%	0.06	0.00	25.17	0.00
(not assigned)	0	0	5	0	0.00%	0.00%	0.03%	0.00%	0.00	0.00	26.28	0.00
S	0	0	0	16	0.00%	0.00%	0.00%	0.11%	0.00	0.00	0.00	4.24
(Riparian)	0	1,829	0	4,155	0.00%	19.80%	0.00%	28.90%	0.00	1,042.70	0.00	2,331.01
<b>42m Cherry Patch Moraines</b>	<b>189</b>	<b>3,804</b>	<b>1,698</b>	<b>1,458</b>	<b>4.73%</b>	<b>95.27%</b>	<b>53.80%</b>	<b>46.20%</b>	<b>71.50</b>	<b>1,316.30</b>	<b>959.36</b>	<b>689.45</b>
A	31	2,748	1,208	1,057	0.78%	68.82%	38.28%	33.49%	10.25	892.90	717.73	405.99
C	23	972	315	335	0.58%	24.34%	9.98%	10.61%	4.60	372.28	176.81	223.86
F	133	77	173	29	3.33%	1.93%	5.48%	0.92%	56.36	48.31	64.76	52.87
G	2	0	0	0	0.05%	0.00%	0.00%	0.00%	0.28	0.00	0.00	0.00
J	0	0	0	27	0.00%	0.00%	0.00%	0.86%	0.00	0.00	0.00	3.96
K	0	0	2	0	0.00%	0.00%	0.06%	0.00%	0.00	0.00	0.06	0.00
(Riparian)	0	7	0	10	0.00%	0.18%	0.00%	0.32%	0.00	2.81	0.00	2.76

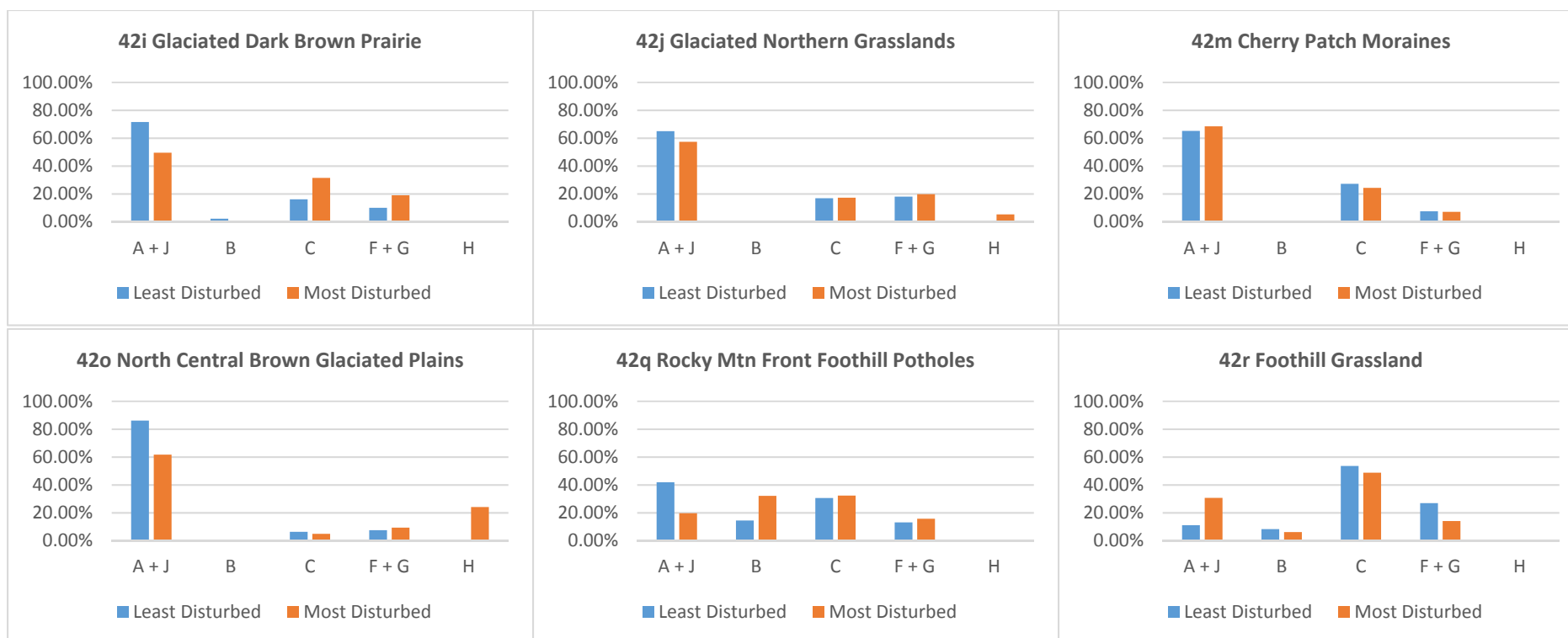
**Table 10** (continued). Water regimes for altered and unaltered wetland-riparian features in least disturbed and most disturbed landscapes for six Level 4 ecoregions in the Prairie Pothole Region of Montana. Altered wetland features are those with special modifiers “d” (partly drained/ditched), “f” (farmed), “h” (diked/impounded), and “x” (excavated); all others were treated as unaltered. Water regimes: A = temporarily flooded; B = saturated; C = seasonally flooded; E = seasonally flooded/saturated; F = semipermanently flooded; G = intermittently exposed; H = permanently flooded; J = intermittently flooded; K = artificially flooded. Note that riparian polygons are not assigned water regimes.

Level 4 Ecoregion Water Regime	# Wetlands				% of Wetlands				Hectares			
	Least Disturbed		Most Disturbed		Least Disturbed		Most Disturbed		Least Disturbed		Most Disturbed	
	Altered	Unaltered	Altered	Unaltered	Altered	Unaltered	Altered	Unaltered	Altered	Unaltered	Altered	Unaltered
<b>42o N. Central Brown Glaciated Plains</b>	<b>50</b>	<b>254</b>	<b>46</b>	<b>155</b>	<b>16.45%</b>	<b>83.55%</b>	<b>22.89%</b>	<b>77.11%</b>	<b>12.18</b>	<b>75.41</b>	<b>49.78</b>	<b>63.65</b>
A	16	120	24	49	5.26%	39.47%	11.94%	24.38%	5.19	39.46	21.53	32.43
C	5	36	3	33	1.64%	11.84%	1.49%	16.42%	1.40	3.60	0.75	3.59
F	29	10	17	27	9.54%	3.29%	8.46%	13.43%	5.59	0.36	5.86	2.35
H	0	0	1	0	0.00%	0.00%	0.50%	0.00%	0.00	0.00	21.25	0.00
J	0	72	1	0	0.00%	23.68%	0.50%	0.00%	0.00	23.50	0.39	0.00
S	0	0	0	1	0.00%	0.00%	0.00%	0.50%	0.00	0.00	0.00	0.25
(Riparian)	0	16	0	45	0.00%	5.26%	0.00%	22.39%	0.00	8.50	0.00	25.02
<b>42q Rocky Mtn Front Foothill Potholes</b>	<b>7</b>	<b>311</b>	<b>30</b>	<b>270</b>	<b>2.20%</b>	<b>97.80%</b>	<b>10.00%</b>	<b>90.00%</b>	<b>1.32</b>	<b>223.92</b>	<b>15.59</b>	<b>359.35</b>
A	1	133	2	48	0.31%	41.82%	0.67%	16.00%	0.09	83.12	0.19	63.77
B	0	19	0	30	0.00%	5.97%	0.00%	10.00%	0.00	28.68	0.00	104.40
C	2	74	3	120	0.63%	23.27%	1.00%	40.00%	0.39	60.27	2.69	102.33
F	4	14	19	33	1.26%	4.40%	6.33%	11.00%	0.84	23.23	8.51	38.43
G	0	25	6	0	0.00%	7.86%	2.00%	0.00%	0.00	1.89	4.19	0.00
S	0	6	0	0	0.00%	1.89%	0.00%	0.00%	0.00	3.18	0.00	0.00
(Riparian)	0	40	0	39	0.00%	12.58%	0.00%	13.00%	0.00	23.55	0.00	50.42
<b>42r Foothill Grassland</b>	<b>98</b>	<b>1,505</b>	<b>172</b>	<b>1,661</b>	<b>6.11%</b>	<b>93.89%</b>	<b>9.38%</b>	<b>90.62%</b>	<b>27.82</b>	<b>1,081.09</b>	<b>66.68</b>	<b>1,394.73</b>
A	5	79	9	269	0.31%	4.93%	0.49%	14.68%	0.54	50.27	2.90	262.33
B	0	88	0	54	0.00%	5.49%	0.00%	2.95%	0.00	37.98	0.00	53.56
C	29	250	28	336	1.81%	15.60%	1.53%	18.33%	6.11	239.25	6.77	415.32
F	64	14	118	221	3.99%	0.87%	6.44%	12.06%	21.17	20.78	46.43	65.08
G	0	519	6	70	0.00%	32.38%	0.33%	3.82%	0.00	81.38	2.25	7.65
H	0	0	0	3	0.00%	0.00%	0.00%	0.16%	0.00	0.00	0.00	2.62
K	0	0	10	0	0.00%	0.00%	0.55%	0.00%	0.00	0.00	6.55	0.00
S	0	0	1	23	0.00%	0.00%	0.05%	1.25%	0.00	0.00	1.79	10.91
(Riparian)	0	555	0	685	0.00%	34.62%	0.00%	37.37%	0.00	651.43	0.00	577.26
<b>Grand Total</b>	<b>3,088</b>	<b>13,075</b>	<b>6,935</b>	<b>13,619</b>	<b>19.11%</b>	<b>80.89%</b>	<b>33.74%</b>	<b>66.26%</b>	<b>1,382.97</b>	<b>6,895.16</b>	<b>4,077.87</b>	<b>7,797.36</b>





**Figure 5.** Percentage of wetlands (based on number of wetlands) in various water regimes contrasted for least disturbed and most disturbed landscapes in six Level 4 ecoregions in the Prairie Pothole Region of Montana. Water regimes: A = temporarily flooded; B = saturated; C = seasonally flooded; F = semipermanently flooded; G = intermittently exposed; H = permanently flooded; J = intermittently flooded.



**Figure 6.** Percentage of wetlands (based on total hectares) in various water regimes contrasted for least disturbed and most disturbed landscapes in six Level 4 ecoregions in the Prairie Pothole Region of Montana. Water regimes: A = temporarily flooded; B = saturated; C = seasonally flooded; F = semipermanently flooded; G = intermittently exposed; H = permanently flooded; J = intermittently flooded.

**Table 11.** Patch size statistics (in hectares) by wetland type in least disturbed and most disturbed landscapes for six Level 4 ecoregions in the Prairie Pothole Region of Montana.

Ecoregion	Wetland Type	# Wetlands		Mean Size (Ha)		Std Dev (Ha)		Minimum (Ha)		Maximum (Ha)	
		Least	Most	Least	Most	Least	Most	Least	Most	Least	Most
42i	Depressional Wetland	0	11	0.00	0.21	0.00	0.12	0.00	0.09	0.00	0.43
42i	Floodplain and Riparian	196	173	0.84	0.42	2.11	0.56	0.08	0.08	20.43	5.25
42i	Freshwater Emergent Wetland	339	284	0.26	0.74	0.47	1.93	0.02	0.02	4.94	20.54
42i	Freshwater Forested/Shrub Wetland	1	5	0.20	0.56	0.00	0.89	0.20	0.10	0.20	2.16
42i	Freshwater Pond	48	85	0.24	0.33	0.41	0.40	0.03	0.01	2.78	2.13
42i	Other	3	0	0.12	0.00	0.08	0.00	0.06	0.00	0.21	0.00
42i	Riparian Emergent	95	49	0.99	0.86	1.59	1.20	0.06	0.03	9.30	5.48
42i	Riparian Forested	6	43	0.76	0.89	1.13	1.41	0.08	0.02	3.05	7.74
42i	Riparian Scrub-Shrub	0	24	0.00	0.80	0.00	0.79	0.00	0.09	0.00	3.07
42i	Riverine	19	15	0.65	0.38	0.62	0.23	0.09	0.04	2.44	0.64
42j	Depressional Wetland	5	30	0.16	0.59	0.08	0.72	0.09	0.09	0.27	2.85
42j	Floodplain and Riparian	337	1,062	0.67	0.60	1.38	1.52	0.08	0.08	12.99	31.50
42j	Freshwater Emergent Wetland	4,915	5,579	0.51	0.60	1.82	1.24	0.00	0.00	80.26	19.65
42j	Freshwater Forested/Shrub Wetland	63	141	0.36	0.43	0.42	0.61	0.04	0.02	2.41	3.96
42j	Freshwater Pond	2,241	1,998	0.56	0.40	2.35	1.04	0.00	0.01	72.78	17.59
42j	Herbaceous Marsh	1	42	0.09	0.84	0.00	2.37	0.09	0.09	0.09	15.04
42j	Lake	13	21	10.67	15.90	14.13	47.34	0.17	0.04	55.36	220.07
42j	Open Water	0	591	0.00	0.13	0.00	0.09	0.00	0.08	0.00	0.81
42j	Other	0	531	0.00	0.45	0.00	0.88	0.00	0.01	0.00	7.83
42j	Riparian Emergent	1,150	1,018	0.58	0.55	1.07	0.97	0.02	0.01	11.89	14.52
42j	Riparian Forested	246	321	0.46	0.78	0.62	1.95	0.02	0.02	4.07	20.87
42j	Riparian Scrub-Shrub	96	936	0.40	0.41	0.53	1.05	0.03	0.01	2.55	26.66
42j	Riverine	149	1,584	0.77	0.53	1.35	1.18	0.00	0.01	8.36	19.58
42j	Swamp/Marsh	0	5	0.00	1.22	0.00	1.30	0.00	0.17	0.00	3.29
42j	Wet meadow	22	516	0.56	0.52	0.61	0.74	0.05	0.01	2.37	4.71
42m	Freshwater Emergent Wetland	3,854	2,958	0.34	0.53	0.50	1.10	0.01	0.01	9.06	22.55
42m	Freshwater Pond	128	185	0.46	0.42	1.29	0.93	0.01	0.01	12.31	6.79
42m	Riparian Emergent	7	5	0.40	0.45	0.35	0.39	0.07	0.23	0.94	1.14
42m	Riparian Forested	0	5	0.00	0.11	0.00	0.05	0.00	0.06	0.00	0.20
42m	Riverine	4	3	1.08	0.21	0.84	0.10	0.33	0.15	2.27	0.33

**Table 11** (continued). Patch size statistics (in hectares) by wetland type in least disturbed and most disturbed landscapes for six Level 4 ecoregions in the Prairie Pothole Region of Montana.

Ecoregion	Wetland Type	# Wetlands		Mean Size (Ha)		Std Dev (Ha)		Minimum (Ha)		Maximum (Ha)	
		Least	Most	Least	Most	Least	Most	Least	Most	Least	Most
42o	Floodplain and Riparian	0	35	0.00	0.64	0.00	0.87	0.00	0.09	0.00	3.61
42o	Freshwater Emergent Wetland	88	86	0.33	0.41	0.51	0.71	0.02	0.01	3.15	3.82
42o	Freshwater Forested/Shrub Wetland	0	2	0.00	0.29	0.00	0.21	0.00	0.14	0.00	0.44
42o	Freshwater Pond	29	50	0.19	0.17	0.18	0.27	0.01	0.01	0.63	1.37
42o	Lake	0	3	0.00	7.15	0.00	12.21	0.00	0.08	0.00	21.25
42o	Other	50	3	0.11	0.30	0.13	0.26	0.01	0.06	0.60	0.57
42o	Riparian Emergent	14	1	0.52	0.21	0.60	0.00	0.09	0.21	2.45	0.21
42o	Riparian Forested	0	1	0.00	0.07	0.00	0.00	0.00	0.07	0.00	0.07
42o	Riparian Scrub-Shrub	3	5	0.70	0.33	0.36	0.27	0.30	0.07	0.97	0.77
42o	Riverine	1	5	0.02	0.33	0.00	0.25	0.02	0.06	0.02	0.69
42o	Swamp/Marsh	119	0	0.32	0.00	0.73	0.00	0.02	0.00	6.23	0.00
42o	Wet meadow		10		2.03		2.50		0.10		6.26
42q	Bog or Fen	2	0	0.27	0.00	0.12	0.00	0.18	0.00	0.36	0.00
42q	Depressional Wetland	10	2	1.35	2.61	1.28	3.44	0.09	0.17	3.60	5.04
42q	Floodplain and Riparian	40	39	0.59	1.29	0.84	2.10	0.09	0.09	4.93	8.98
42q	Freshwater Emergent Wetland	132	198	0.65	1.34	1.31	3.56	0.02	0.03	11.31	36.63
42q	Freshwater Forested/Shrub Wetland	19	0	0.92	0.00	1.00	0.00	0.06	0.00	3.57	0.00
42q	Freshwater Pond	39	46	0.31	1.00	0.69	1.60	0.03	0.04	4.09	7.29
42q	Herbaceous Marsh	0	1	0.00	2.58	0.00	0.00	0.00	2.58	0.00	2.58
42q	Lake	2	0	7.45	0.00	7.69	0.00	2.01	0.00	12.89	0.00
42q	Open Water	2	0	0.09	0.00	0.00	0.00	0.09	0.00	0.09	0.00
42q	Other	58	7	0.86	0.47	1.00	0.51	0.04	0.05	4.81	1.34
42q	Riverine	14	0	0.48	0.00	0.41	0.00	0.14	0.00	1.58	0.00
42q	Wet meadow	0	7	0.00	0.25	0.00	0.13	0.00	0.09	0.00	0.43
42r	Bog or Fen	0	1	0.00	0.17	0.00	0.00	0.00	0.17	0.00	0.17
42r	Depressional Wetland	17	33	1.31	0.38	1.40	0.38	0.09	0.09	4.99	1.56
42r	Floodplain and Riparian	491	685	1.26	0.84	2.60	2.05	0.08	0.08	24.70	30.57
42r	Freshwater Emergent Wetland	283	395	0.39	1.10	0.96	2.31	0.02	0.02	10.78	25.98
42r	Freshwater Forested/Shrub Wetland	92	109	1.95	1.94	4.23	2.44	0.02	0.05	36.03	17.05
42r	Freshwater Pond	585	218	0.17	0.25	0.32	0.45	0.02	0.01	4.73	4.25
42r	Herbaceous Marsh	0	37	0.00	0.90	0.00	2.17	0.00	0.09	0.00	12.78
42r	Lake	1	3	19.12	3.87	0.00	4.45	19.12	0.84	19.12	8.98
42r	Open Water	0	183	0.00	0.13	0.00	0.10	0.00	0.08	0.00	1.05
42r	Other	32	51	0.36	0.73	0.78	1.05	0.01	0.05	4.49	5.43
42r	Riparian Emergent	26	0	0.41	0.00	0.34	0.00	0.03	0.00	1.23	0.00
42r	Riparian Forested	9	0	0.40	0.00	0.49	0.00	0.09	0.00	1.65	0.00
42r	Riparian Scrub-Shrub	13	0	0.46	0.00	0.72	0.00	0.07	0.00	2.50	0.00
42r	Riverine	27	118	0.69	0.55	1.35	1.49	0.03	0.03	6.66	15.51
42r	Wet meadow	27	0	0.30	0.00	0.48	0.00	0.02	0.00	2.42	0.00

**Table 12.** Wetland density in least disturbed and most disturbed landscapes for six Level 4 ecoregions in the Prairie Pothole Region of Montana. Density is calculated as total wetland hectares / total analysis unit (AU) hectares.

Level 4 Ecoregion		Least Disturbed				Most Disturbed			
		# Wetlands	Wetland Ha	AU Ha	Wetland Density	# Wetlands	Wetland Ha	AU Ha	Wetland Density
42i	Glaciated Dark Brown Prairie	707	375.79	18,323.78	0.02	689	420.89	18,165.96	0.02
42j	Glaciated Northern Grasslands	9238	5,092.79	278,070.03	0.02	14375	7,855.75	278,241.07	0.03
42m	Cherry Patch Moraines	3993	1,387.80	23,856.04	0.06	3156	1,648.81	25,750.65	0.06
42o	North Central Brown Glaciated Plains	304	87.59	6,284.52	0.01	201	113.43	6,287.68	0.02
42q	Rocky Mtn Front Foothill Potholes	318	225.25	12,542.79	0.02	300	374.94	7,087.94	0.05
42r	Foothill Grassland	1603	1,108.92	59,380.40	0.02	1833	1,461.41	59,601.13	0.02

**Table 13.** Distance between wetland/riparian features in least disturbed and most disturbed landscapes by analysis unit in six Level 4 ecoregions in the Prairie Pothole Region of Montana.

Analysis Unit	Distance Between Wetlands											
	# Wetlands		Mean		Std Dev		Minimum		Maximum		Range	
	Least	Most	Least	Most	Least	Most	Least	Most	Least	Most	Least	Most
42i-1	192	202	146.76	163.05	252.60	159.12	19.83	30.32	2,068.54	1,396.86	2,048.70	1,366.54
42i-2	247	241	151.37	163.73	159.71	151.10	29.42	31.26	1,337.36	1,491.79	1,307.94	1,460.53
42i-3	268	244	148.52	162.39	139.45	232.44	16.07	10.45	967.91	1,955.12	951.84	1,944.67
42j-1	58	624	356.98	92.40	358.35	80.63	39.95	14.39	1,544.40	631.02	1,504.45	616.63
42j-2	174	266	165.95	139.41	191.85	152.08	7.79	14.01	818.32	1,059.50	810.52	1,045.49
42j-3	127	195	142.41	193.45	191.32	243.50	13.82	20.58	882.71	2,146.32	868.89	2,125.75
42j-4	182	187	194.37	259.46	229.17	274.95	11.48	24.73	1,655.00	2,386.49	1,643.52	2,361.76
42j-5	152	196	172.61	187.37	279.15	194.52	13.87	19.20	1,881.04	1,119.04	1,867.17	1,099.84
42j-6	265	342	150.26	171.43	174.31	168.38	12.20	12.21	1,108.11	1,258.08	1,095.92	1,245.87
42j-7	591	651	90.77	118.92	104.88	140.53	11.96	10.63	1,162.38	971.62	1,150.42	960.99
42j-8	156	655	199.95	93.10	231.48	135.94	47.18	11.02	1,689.92	1,201.29	1,642.74	1,190.27
42j-9	321	449	136.08	139.59	216.74	173.06	13.20	8.86	1,688.47	1,853.12	1,675.26	1,844.26
42j-10	539	558	144.93	157.40	139.62	187.48	13.54	12.57	1,271.84	1,788.40	1,258.30	1,775.83
42j-11	474	793	177.77	128.51	163.84	122.42	22.87	5.61	1,613.51	909.92	1,590.64	904.31
42j-12	1094	947	137.35	164.47	123.35	167.14	13.41	12.52	1,301.34	1,092.76	1,287.93	1,080.24
42j-13	536	1171	156.85	133.56	230.53	145.03	8.96	7.24	2,372.77	1,313.25	2,363.81	1,306.01
42j-14	1689	4292	165.25	109.78	194.48	132.01	13.75	6.99	3,086.10	1,194.68	3,072.35	1,187.69
42j-15	2880	3042	140.66	149.60	169.54	172.52	9.45	9.78	1,805.39	1,667.03	1,795.94	1,657.24
42m-1	1427	1137	90.35	96.48	57.71	65.85	12.69	10.77	406.35	472.16	393.66	461.39
42m-2	652	945	110.48	117.72	109.31	86.70	12.51	12.88	1,286.06	582.93	1,273.54	570.05
42m-3	1914	1074	85.94	133.66	66.73	109.81	9.19	14.26	699.12	1,394.29	689.92	1,380.03
42o-1	304	199	155.20	207.81	158.24	200.89	18.93	17.27	2,048.14	984.27	2,029.21	967.00
42q-1	91	128	304.33	194.96	275.40	177.36	54.68	42.13	1,552.79	1,229.23	1,498.11	1,187.10
42q-2	227	172	179.36	217.45	165.48	128.99	17.32	49.27	843.32	956.66	826.00	907.39
42r-1	91	254	306.28	162.66	269.43	145.29	36.32	27.57	1,683.91	1,381.30	1,647.58	1,353.74
42r-2	93	220	296.85	183.94	331.99	208.92	26.33	21.33	1,917.60	1,354.57	1,891.28	1,333.23
42r-3	279	586	252.79	151.54	219.59	176.92	41.94	28.55	1,308.66	1,298.79	1,266.71	1,270.24
42r-4	830	166	116.19	283.09	162.45	327.28	17.04	33.17	2,230.94	1,978.35	2,213.90	1,945.18
42r-5	310	607	209.55	180.90	264.98	161.38	10.22	24.04	1,479.77	1,192.95	1,469.55	1,168.91

**Table 14.** Membership of wetland/riparian features in landscape complexes in least disturbed and most disturbed landscapes for six Level 4 ecoregions in the Prairie Pothole Region of Montana. Landscape complex scores of 0 = not part of a landscape complex; 3 = part of a landscape complex with 5-9 features/hectare; and 5 = part of a landscape complex with >10 features/hectare.

Level 4 Ecoregion		Score	# Wetlands		Hectares		% Area	
			Least	Most	Least	Most	Least	Most
42i	Glaciated Dark	0	550	435	347.46	212.07	92.46%	50.39%
	Brown Prairie	3	157	254	28.33	208.81	7.54%	49.61%
	<b>Total</b>		707	689	375.79	420.89	100.00%	100.00%
42j	Glaciated Northern	0	7,392	6,407	4,127.55	3,911.87	81.05%	49.80%
	Grasslands	3	1,706	6,070	909.47	3,009.99	17.86%	38.32%
		5	140	1,898	55.77	933.89	1.10%	11.89%
	<b>Total</b>		9,238	14,375	5,092.79	7,855.75	100.00%	100.00%
42m	Cherry Patch	0	82	65	22.01	42.82	1.59%	2.60%
	Moraines	3	204	629	84.65	360.58	6.10%	21.87%
		5	3,707	2,462	1,281.13	1,245.41	92.31%	75.53%
	<b>Total</b>		3,993	3,156	1,387.80	1,648.81	100.00%	100.00%
42o	North Central Brown	0	82	201	27.70	113.43	31.62%	100.00%
	Glaciated Plains	3	222	0	59.89	0.00	68.38%	0.00%
	<b>Total</b>		304	201	87.59	113.43	100.00%	100.00%
42q	Rocky Mountain Front	0	318	225	225.25	320.00	100.00%	85.35%
	Foothill Potholes	3	0	75	0.00	54.93	0.00%	14.65%
	<b>Total</b>		318	300	225.25	374.94	100.00%	100.00%
42r	Foothill Grassland	0	953	1,629	815.51	1,329.82	73.54%	91.00%
		3	554	204	264.65	131.59	23.87%	9.00%
		5	96	0	28.77	0.00	2.59%	0.00%
	<b>Total</b>		1,603	1,833	1,108.92	1,461.41	100.00%	100.00%

**Table 15.** *Wetland mosaics in least disturbed and most disturbed landscapes, Prairie Pothole Region, Montana.*

	<b>Least Disturbed</b>	<b>Most Disturbed</b>
<b>Total mosaics</b>	<b>324</b>	<b>559</b>
<b>Number of wetlands per mosaic</b>		
minimum	5	5
maximum	10,815	10,815
mean	100.94	57.13
standard deviation	662.11	500.15
total	32,706	31,934
<b>Mosaic hectares</b>		
minimum	0.86	0.24
maximum	17,607.37	17,607.37
mean	206.45	128.53
standard deviation	1,353.60	1,038.10
total	66,888.77	71,848.98



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